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ARTIFICIAL INTELLIGENCE AS A MEANS OF CREATING MUSIC

Abstract. *Creativity, in particular in music, is a set of algorithms and patterns. Scientists are constantly trying to develop the algorithm of creativity that would teach artificial intelligence to create musical compositions as well as people do. This article is devoted to the consideration of two approaches to the creation of musical compositions, which are quite common for problems of this kind.*

Keywords: *artificial intelligence, musical compositions, algorithms.*

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ИСКУССТВЕННЫЙ ИНТЕЛЛЕКТ КАК СРЕДСТВО СОЗДАНИЯ МУЗЫКИ

Аннотация. *Творчество, в частности музыкальное – это набор алгоритмов и шаблонов. Ученые постоянно предпринимают попытки разработать тот самый алгоритм творчества, который научил бы* *искусственный интеллект создавать музыкальные композиции, подобно людям. Статья посвящена рассмотрению двух подходов к созданию музыкальных композиций, которые довольно востребованы для решения подобных задач.*

Ключевые слова: *искусственный интеллект, музыкальные композиции, алгоритмы.*

Introduction

Everything in the world is mathematics. If you look closely, you will find out that there is an algorithm or a pattern literally in everything. It is clear enough that mathematics is a foundation for exact science, however, its presence in more ordinary and more distant from exact science things is not as obvious, so it is a good idea to give an example of how mathematics manifests itself in things around us. For example, in nature. One of the most common mathematical phenomena - the «phi» number or «golden ratio» - it occurs at every step - there are 1.68 times more females in the hive than males, there are 1.68 times more petals in the flower at each next level than in the previous one, and even if you measure the distance from the shoulder to the fingertips, then divide it by the distance from the elbow to the same fingertips, you get the number 1.618. Isn't that amazing?

But, besides this, mathematics is also the basis of art. At least for the music. There is a pattern in absolutely any composition. It means that any melody is built according to a certain algorithm. It is a well-known fact, but no one delves into this as deep as researchers who are trying to teach a computer to compose a melody.

A person, while creating compositions, is guided not by the presence of patterns and their correctness, he is almost unaware of them, but by his own subjective feelings. The machine does not have a sense of beauty, so researchers are faced with an extremely difficult task - to derive an algorithm for all that is beautiful in music and program it into the machine.

By its irrational nature, music is difficult to algorithmize; majority of people are still convinced that computer algebra and music harmony are absolutely incompatible things. However, these areas have much more in common than it might seem at first glance.

In this article, the following approaches to creating computer musical compositions will be considered: grammars and cellular automata.

Approaches applied to creating music composition

Grammars

A formal grammar in general terms can be described as following: a set of rules for expanding top-level symbols into a more detailed set of simple symbols representing elements of formal languages. A «symbol» can be anything. It might be a letter of lower-case or upper-case, punctuation marks or something else, including notes. The essence of this group of methods is that words are generated by repeatedly applying rewriting rules, in a sequence of so-called derivation steps. In turn, words are formed from the «symbols», the set of which must be determined.

This group of methods is suitable for representing systems that have a hierarchical structure, reflected in the recursive application of rules.

Music is composed according to certain rules of formal grammar. Therefore, it is very important to define a set of rules according to which the composition will be formed. Another important aspect is the correspondence between formal grammar and the musical objects that it creates.

The problem with the grammatical approach to algorithmic composition is that it is difficult to manually define a set of grammatical rules to create good compositions. This problem can be solved by automatically generating grammar rules.

One of the formal grammar’s variants is Lindenmayer Systems. The difference between them and classic formal grammars is in the way rules are applied. So, in formal grammar only one rule is applied at each step, while in systems of this type all possible rules are applied simultaneously. The result is some kind of graph-like behavior, so they are particularly well suited to represent the characteristics of hierarchical self-similarity. L-systems are much easier to understand and use than formal grammar and this is what helped them to gain widespread use in algorithmic composition.

Example of L-Systems

Initially, there is a set of variables, a rule, and an input parameter. For example:

- variables : A, B
- axiom : A
- rules : (A → AB), (B → A)

On each step of algorithms variables are changed according to the rules. schematically it looks like following (Fig. 1).

```
n=0:            A           start (axiom/initiator)
               / \
n=1:          A   B         the initial single A spawned into AB by rule (A → AB), rule (B → A) couldn't be applied
             /|     \
n=2:        A B      A      former string AB with all rules applied, A spawned into AB again, former B turned into A
           / | |      | \
n=3:       A B A      A B   note all A's producing a copy of themselves in the first place, then a B, which turns ...
          / | | | \    | \ \
n=4:      A B A A B    A B A  ... into an A one generation later, starting to spawn/repeat/recurse then
```

Fig. 1. L-System - tree

Cellular Automata

A cellular automaton (CA) is another complex mathematical algorithm used to sequence a specific set of input data.

A CA is a discrete dynamic system composed of very simple computational units (cells) usually arranged in an ordered n-dimensional grid. A cell can only assume a finite number of states - 0 or 1.

For a cellular automaton to work, it is required to specify the initial state of all the cells and the rules for the transition of units from one state to another.

The state of each unit is updated at each time step, using the rules for the transition, its own state and states of its neighbors. Neighbors are all cells located in the «neighborhood». For example, a neighborhood can be defined as all cells at a distance of no more than two from the current one. Usually, the transition rules are the same for all cells and apply immediately to the entire grid.

For clarity, we will give an example of how a cell changes its state depending on the state of its neighbor.

- First, let's take a simple rule like 110.
- $110_{10} = 01101110_2$

- Let's write the digits of the binary representation of the number into the table 1:

111	110	101	100	011	010	001	000
0	1	1	0	1	1	1	0

Table 1 - binary representation of the number

Depending on the states of the neighbor on the left, the cell itself and the neighbor on the right (the first row of the table) at the next step, the cell will take one of the states indicated in the second row.

It can be presented even more clearly as follows (Fig. 2):

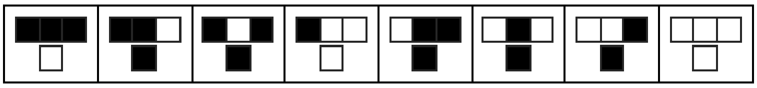

Fig. 2. All possible variants of the cell position depending on the incoming rule

Cellular automata are used in many disciplines across Science and the Humanities as dynamical models of complex spatial and temporal patterns emerging from the local interaction of many simple units; music composition is just one of these disciplines. Cellular automata can be used to generate fractal patterns and discrete versions of chaotic dynamical systems, but they also represent an alternative computational paradigm to realize algorithmic composition.

Conclusion

Music is a type of creativity. But the approaches to teaching this sort of creativity to a machine are exclusively mathematical.

In this paper we have focused on two well-known sequencing paradigms – grammars a cellular automation. Both these approaches have something in common – they require the presents of a set of rules which will be applied while creating specific sequences. They are commonly used in various fields of science but are also extremely widespread in computerized music creation.

The story of human’s attempt to create computerized music using different algorithms is very rich, however, the biggest achievements are still awaiting.

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